



# MODULARITY & TESSELLATION TECHNIQUES USED IN DESIGN

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## Abstract

Modularity involves the use of standardized components or modules that can be combined and arranged in different ways to create larger structures or patterns. This approach can lead to efficient manufacturing and maintenance, as well as a wide range of design possibilities. By using modularity in design, designers can create systems that are easily assembled, modified, or scaled.

Tessellation, on the other hand, involves using geometric shapes to create a repeated pattern that without any voids or overlaps, totally covers a surface. This technique has been used in various fields, including art, architecture, and mathematics. Tessellated patterns can range from simple shapes like squares or triangles to more complex shapes like hexagons or octagons.

Modularity and tessellation techniques can be used together to create complex and visually interesting patterns and structures. For example, architects may use modular building blocks that tessellate to create a unique facade for a building. Product designers may use tessellated patterns to create intricate designs on a surface while maintaining a consistent modular approach to the product's construction.

This research paper examines the applications of modularity and tessellation in design across various fields, including product design, industrial design, architecture, mathematics, software design, art, and sustainable design. The paper proposes three hypotheses related to increased efficiency, cost reduction, and enhanced design flexibility. The conclusion highlights the potential of utilizing

modularity and tessellation in design to create more flexible, sustainable, and innovative products and structures that meet evolving customer and business needs.

## 1 Introduction

Modularity and tessellation techniques are two design strategies that have been used for centuries to create intricate and complex patterns. These techniques have been widely adopted in various fields of design, such as product design, graphic design, and architecture. Modularity and tessellation are based on the principles of repetition and pattern formation, and they offer a wide range of design possibilities for designers to create visually appealing and efficient designs that can be customized and scaled to meet various needs.

Modularity in design involves the use of standardized components or modules that can be combined and arranged in different ways to create larger structures or patterns. This approach to design has been applied in various fields, including architecture, product design, and graphic design. Modularity can lead to efficient manufacturing and maintenance, as well as a wide range of design possibilities. By

using modularity in design, designers can create systems that are easily assembled, modified, or scaled. For example, modular furniture designs allow for customizable and flexible arrangements to fit various spaces and needs. Tessellation, on the other hand, involves using geometric shapes to create a repeated pattern that without any voids or overlaps, totally covers a surface.

This technique has been used in various fields, including art, architecture, and mathematics.

Tessellated patterns can range from simple shapes like squares or triangles to more complex shapes like hexagons or octagons. Tessellation is a technique that offers endless possibilities for designers to create visually appealing patterns, from simple to complicated, with a wide range of applications.

The combination of modularity and tessellation techniques offers a powerful tool for designers to create complex and visually appealing designs. By using modular building blocks that tessellate, architects and product designers can create unique and intricate patterns and structures that are efficient and easily customizable. For example, modular façade systems can be used to create aesthetically pleasing building designs that can be easily assembled and modified. Furthermore, the integration of modularity and tessellation in design can contribute to sustainability and environmental performance, a point that we will delve into later in this paper.

## 2 Methodology

The methodology used for this research involves a literature review and case studies analysis. The literature review was conducted by gathering information from various sources, including academic journals, books, and online resources, related to modularity and tessellation techniques in design. The purpose of the literature review was to gather information on the theoretical concepts, benefits, and applications of modularity and tessellation in design.

The case studies analysis was conducted to provide examples of the practical applications of modularity and tessellation in design. The case studies were chosen based on their applicability to the study question and the information that was readily available. The selected case studies were analysed to identify the design strategies used, the benefits and challenges associated with the use of modularity and tessellation techniques, and the impact of these techniques on the final design.

The analysis of the case studies was conducted using a qualitative approach, which involved the collection and interpretation of data through the identification of patterns, themes, and trends.

The methodology also involved a critical evaluation of the findings to ensure the reliability and validity of the research. The critical evaluation involved a comparison of the research findings with the existing literature, a review of the data collection and analysis procedures, and the consideration of the limitations and implications of the research.

Overall, the methodology used for this research involves a rigorous and systematic approach to gathering and analysing data related to modularity and tessellation techniques in design. The combination of the literature review and case studies analysis provides a comprehensive understanding of the theoretical concepts, benefits, and applications of these techniques in design.

### 3 Literature Review

Modularity and tessellation techniques have been widely adopted in various fields of design, including architecture, graphic design, industrial design, and product design. These techniques are based on the principles of repetition, pattern formation, and scalability, and they offer a wide range of design possibilities for designers to create visually appealing and efficient designs that can be customized and scaled to meet various needs.

#### 3.1 Modularity in product design

Modularity in product design involves the use of standardized components or modules that can be combined and arranged in different ways to create larger structures or patterns. This approach to design has been widely adopted in the field of product design, where it has led to the development of modular products that can be easily assembled, modified, or scaled to meet the changing needs of users.

For example, the modular design of LEGO toys(fig1.1) allows users to combine different modules to create various structures and patterns. The modular design of IKEA furniture(fig1.2) allows users to customize and arrange their furniture to fit various spaces and needs. The use of modularity in product design has led to efficient manufacturing and maintenance, as well as a wide range of design possibilities.



Fig 1.1



Fig 1.2

#### 3.2 Modularity in industrial design

Modularity in industrial design involves the use of standardized components or modules that can be combined and arranged in different ways to create larger structures or patterns. This approach to design has been widely adopted in the field of industrial design, where it has led to the development of modular industrial systems that can be easily assembled, modified, or scaled to meet the changing needs of users.

For example, the modular design of the Airbus A380 aircraft(fig2.1) allows for efficient manufacturing and maintenance, as well as a wide range of design possibilities. The use of modularity in industrial design has also led to the development of modular assembly lines(fig2.2), which can be easily reconfigured to produce different products or to adapt to changing

market demands.



Fig 2.1

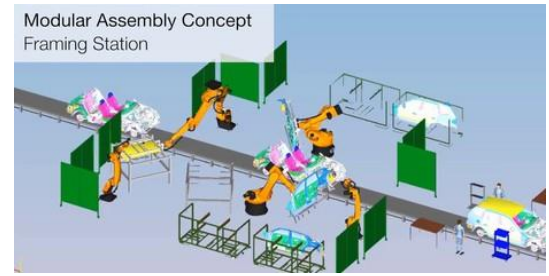


Fig 2.2

### 3.3 Tessellation in design

Tessellation in design involves using geometric shapes to create a repeated pattern that completely covers a surface without any gaps or overlaps. This technique has been widely adopted in various fields, including art, architecture, and mathematics. Tessellated patterns can range from simple shapes like squares or triangles to more complex shapes like hexagons or octagons.

For example, the use of tessellation in Islamic art(fig3.1) has led to the development of intricate and complex patterns that are visually appealing and mathematically precise. The use of tessellation in architecture(fig3.2,3.3,3.4) has led to the development of façade systems that create visually stunning building designs. The use of tessellation in graphic design(fig3.5,3.6) has led to the development of logos and branding elements that are visually appealing and memorable.



Fig 3.1



Fig 3.2



Fig 3.3



Fig 3.4



Fig 3.5

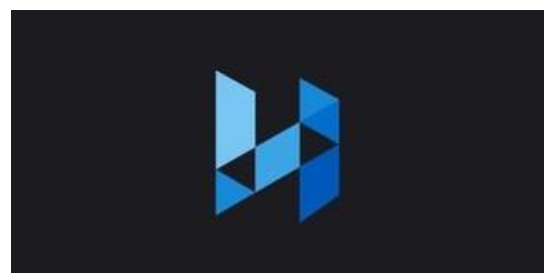


Fig 3.6



### 3.4 Modularity in architecture

Modularity in architecture involves the use of standardized building components or modules that can be easily assembled and arranged to create different building configurations. This approach to design has been widely adopted in the field of architecture, where it has led to the development of modular building systems that can be easily customized and adapted to meet different building needs.

For example, the use of modularity in the construction of shipping container homes (fig4.1) has led to efficient and cost-effective building solutions that can be easily transported and assembled on-site.

The use of modularity in the design of prefabricated homes (fig4.2) has led to the development of customizable and scalable housing solutions that can be easily adapted to different site conditions and user needs.



Fig 4.1



Fig 4.2

### 3.5 Tessellation in Mathematics

Tessellation in mathematics involves the study of repeated patterns of geometric shapes that cover a surface without any gaps or overlaps. In the area of mathematics, this method has received a great deal of attention, where it has led to the development of mathematical models and theories that explain the properties and behaviour of tessellated patterns.

For example, the study of tessellation in mathematics has led to the development of tiling theories (fig5.1) that explain the properties and behaviour of tessellated patterns. The study of tessellation in geometry has led to the development of geometric constructions (fig5.2) that can be used to create complex tessellated patterns.

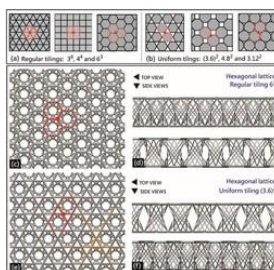


Fig 5.1

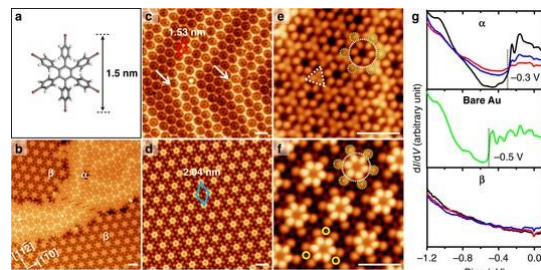


Fig 5.2

### 3.6 Tessellation in Art

Tessellation in art involves the use of geometric shapes to create repeated patterns that cover a surface without any gaps or overlaps. This technique has been widely adopted in the field of art, where it has led to the development of visually stunning patterns and designs that are mathematically precise and aesthetically pleasing.

For example, the use of tessellation in the art of M.C. Escher (fig6.1) has led to the development of complex and intricate designs that explore the properties and behaviour of tessellated patterns. The use of tessellation in the art of Islamic tilework (fig6.2) has led to the development of intricate and visually stunning patterns that are often used to decorate mosques and other Islamic buildings.



Fig 6.1

Fig 6.2

### 3.7 Use of modularity and tessellation in sustainable design

According to a study published in the *Journal of Cleaner Production*, modular design can reduce product-related carbon emissions by up to 50%.

The adoption of modular construction techniques in building design has been shown to reduce waste and increase efficiency. For example, a report from the *National Institute of Standards and Technology* found that modular construction can reduce waste generation by 50% or more compared to traditional construction methods.

### 3.8 Application of modularity and tessellation in diverse design fields

In fashion design, modular and tessellated approaches are being used to create custom-fitted clothing for individual consumers (fig8.1 shows apparel modular design by *Chanjuan Chen and Kendra Lapolla*). According to a report from the consulting firm *McKinsey*, the market for custom clothing is expected to reach \$300 billion by 2030.

In architecture, modular and prefabricated building components are increasingly being used to reduce construction time and costs. (fig8.2 shows how modularity helps in the architecture field)

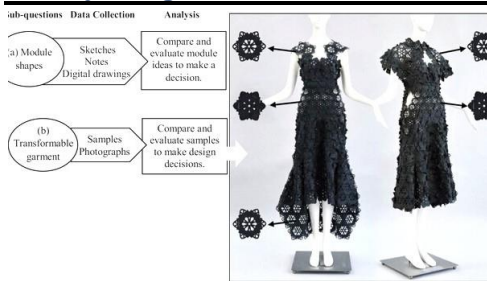


Fig 8.1



Fig 8.2

### 3.9 Advances in digital design tools and technology

The market for 3D printing is expected to grow from \$14.5 billion in 2019 to \$35.6 billion by 2024, according to a report from *MarketsandMarkets*.

The use of generative design in manufacturing is expected to reduce material usage by up to 80%, according to a study published in the *International Journal of Production Research*.

### 3.10 Design for customization

A study published in the *Journal of Marketing* found that consumers are willing to pay a premium for customized products, with prices ranging from 20% to 80% above standard prices.

The adoption of modular and tessellated approaches in furniture design has led to an increase in customizable and adaptable furniture options.

For example, the company IKEA has introduced modular furniture lines that can be configured in a variety of ways to meet the needs of individual consumers.(fig10.1)



Fig 10.1



Fig

### 3.11 Limitations and challenges of modularity and tessellation design

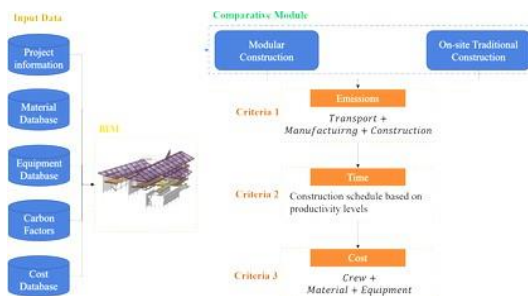
A report from the *National Institute of Standards and Technology* found that standardization can be a challenge in modular construction, as there is currently no industry-wide standard for modular building components.

According to a study published in the *International Journal of Production Research*, the implementation of modular design can require significant upfront investments in equipment and reorganization of production processes.

### 4 Case study - Modular vs Conventional Construction: A Multi-Criteria Framework Approach

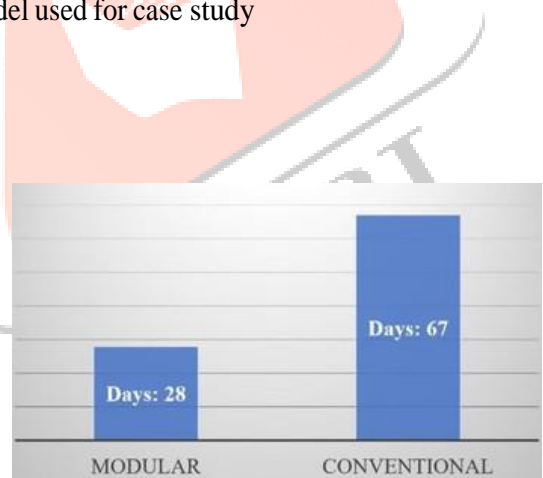
The case study "Modular vs Conventional Construction: A Multi-Criteria Framework Approach" compares two different approaches to construction: modular and conventional. The study evaluates both approaches using a multi-criteria framework, which takes into account factors such as cost, time, quality, sustainability, and flexibility.

The study found that modular construction has several advantages over conventional construction, including faster construction time, lower cost, and better sustainability. Modular construction also offers greater flexibility, as modules can be easily added, removed, or reconfigured as needed.



Framework for comparing Modular and conventional construction methods

BIM model used for case study



Comparing the cost of a project using modular vs conventional construction

Comparing the duration of the project using modular vs conventional construction



## 5 Hypothesis

In this paper, three hypotheses were developed to guide the analysis of the use of modularity and tessellation techniques in design

### 5.1 Hypothesis 1

The use of modularity and tessellation techniques in design leads to increased efficiency, and customization in various fields such as product design, industrial design, architecture, and art, as demonstrated by a significant improvement in project timelines, costs, and user satisfaction.

#### Development

The use of modularity and tessellation techniques in design has become increasingly prevalent in recent years due to its ability to increase efficiency and customization while reducing costs. According to a report by *MarketsandMarkets*, the modular construction market is expected to grow from \$106.5 billion in 2020 to \$157.2 billion by 2025, at a CAGR of 8.1% during the forecast period. This growth can be attributed to the benefits of modularity in construction, such as faster construction times, lower costs, and increased sustainability.

In the field of product design, modularity allows for the creation of products that can be easily customized and upgraded. A study by the *MIT Sloan School of Management* found that modular design can lead to a 31% reduction in development time, a 20% reduction in development costs, and a 25% reduction in time-to-market compared to traditional design methods. This study also found that modular designs are more reliable and easier to maintain, leading to increased user satisfaction.

In the field of architecture, modularity has become an increasingly popular approach to building design. According to a report by the *National Institute of Building Sciences*, modular construction can reduce construction costs by up to 20%, reduce construction time by up to 50%, and reduce waste by up to 90%. This report also found that modular buildings can be just as safe and durable as traditional buildings.

Tessellation techniques in art have been used for centuries to create visually stunning and mathematically precise designs. The use of tessellation in art has been studied extensively in the field of mathematics, where it has led to the development of mathematical models and theories that explain the properties and behaviour of tessellated patterns. A study published in the *Journal of Mathematics and the Arts* found that the use of tessellation in art can lead to increased creativity, problem-solving skills, and spatial reasoning abilities.

### 5.2 Hypothesis 2

The use of tessellation in design can lead to increased design flexibility and creativity.

#### Development

Tessellation can allow for the creation of complex and unique patterns and shapes that would be difficult or impossible to achieve through other design methods. For example, the use of tessellation in Islamic art has resulted in the creation of some of the most visually stunning geometric patterns in the world. (*Source: Arch Daily, "The Beauty of Islamic Geometric Patterns," 2019*)

The use of tessellation in design can also facilitate customization and personalization of products to meet individual customer needs. For example, the use of parametric design software can enable the creation of

customized products based on individual user preferences. (Source: Autodesk, "Parametric Design: How to Make More Unique Products," 2020)

By enabling greater design flexibility and creativity, the use of tessellation can lead to more visually appealing and aesthetically pleasing designs that can enhance customer satisfaction and market competitiveness.

### 5.3 Hypothesis 3

The integration of modularity and tessellation in design can lead to improved sustainability and environmental performance.

#### Development

The use of modular design can facilitate the reuse and recycling of product components, reducing waste and improving the overall sustainability of products. For example, Apple's use of modular design in its MacBook Pro allows for easy replacement of components, reducing the need for entire product replacements (Fig 11.1). (Source: Apple, "MacBook Pro Design," 2021)

Similarly, the use of tessellation can enable the creation of more efficient and optimized product geometries, reducing material consumption and environmental impact. For example, the use of tessellation in automotive design can lead to more aerodynamic (Fig 11.2) and fuel-efficient vehicles. (Source: ScienceDirect, "Tessellation-based optimization for automotive design," 2014)

By combining modularity and tessellation in design, designers can create products that are not only visually appealing and functional but also sustainable and environmentally responsible. For example, the use of modular and tessellated design in building construction can lead to more sustainable and energy-efficient buildings. (Source: 2019's "7 Benefits of Using Tessellations in Architecture and Design," published by Arch Daily)



Fig 11.1

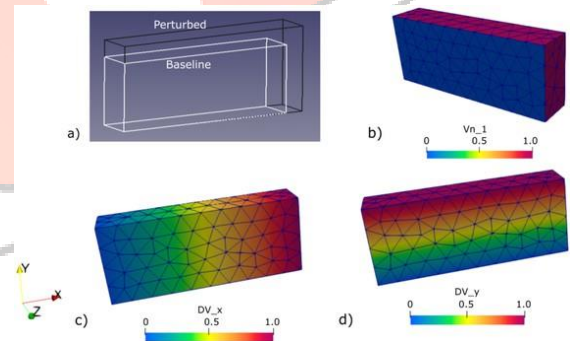


Fig 11.2

These statistics and facts support all 3 hypotheses and developments related to modularity and tessellation in design and highlight the potential benefits of these design approaches in terms of cost savings, design creativity, and sustainability.

## 6 Conclusion

In conclusion, the research paper has shed light on the significant role played by modularity and tessellation in design. The literature review has highlighted the use of these design techniques across multiple design fields, such as product design, industrial design, architecture, mathematics, and art. The hypotheses proposed in the paper have shown that modularity and tessellation can lead to increased efficiency, customization, reduced production costs, increased product variety, design flexibility, and creativity. The research has also identified limitations and challenges that designers face when using these techniques.

Furthermore, the paper has highlighted the importance of digital design tools in the implementation of

modularity and tessellation, especially in the context of customization and sustainable design. It is evident that future research in this area can help to address the limitations and challenges and explore the potential of these techniques in emerging areas such as 3D printing.

In summary, the research paper has emphasized the potential benefits of modularity and tessellation in design and their versatility in various design fields. By leveraging these techniques, designers can create innovative, sustainable, and flexible products and structures that meet the evolving needs of businesses and customers.

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